Further Details on TPC Cost/Schedule/Resources

KLAUS DEHMELT

ASSOCIATE LABORATORY DIRECTOR'S DESIGN REVIEW OF THE sPHENIX TRACKER

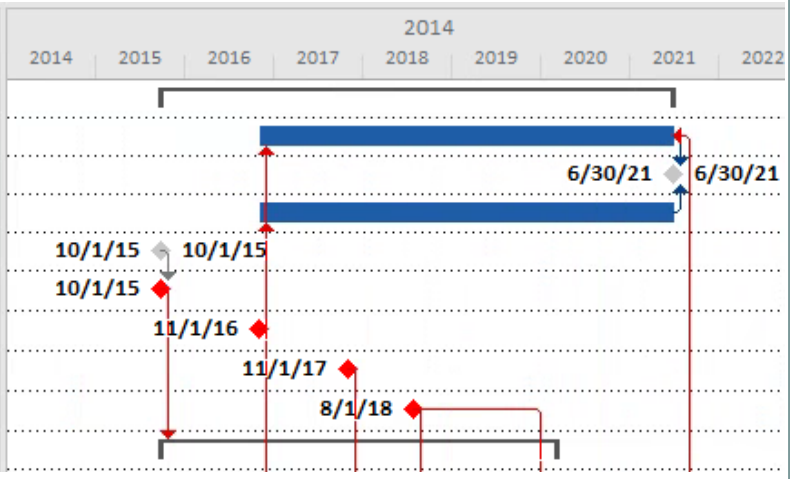
SEPTEMBER 07, 2016

Stony Brook University | The State University of New York

PHENIX

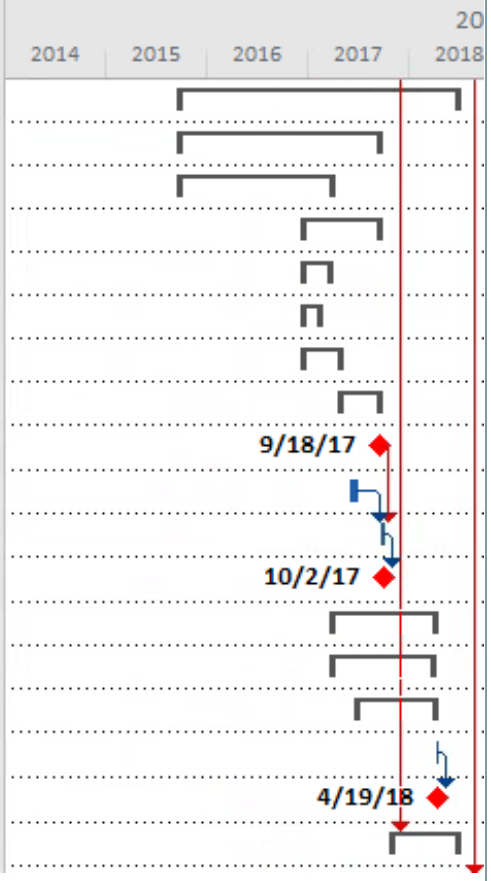
Project Schedule

WBS	Task Name	Duration	Start	Cost
1.3.1	**Tracker Management**	**1432 days**	**Thu 10/1/15**	**$0**
1.3.1.1	Manage L2 Tracker Subsystem	1161 days	Tue 11/1/16	$0
	Complete Commissioning	0 days	Wed 6/30/21	$0
1.3.1.3	TPC L3 Management	1161 days	Tue 11/1/16	$0
	Start Pre R&D	0 days	Thu 10/1/15	$0
1.3.1.5	Start Pre R&D	0 days	Thu 10/1/15	$0
1.3.1.6	Receive DOE CD-0	0 days	Tue 11/1/16	$0
1.3.1.7	Receive DOE CD-1	0 days	Wed 11/1/17	$0
1.3.1.8	Receive DOE CD-2/3	0 days	Wed 8/1/18	$0
1.3.2	**Time Projection Chamber**	**1105 days**	**Thu 10/1/15**	**$4,827,405**



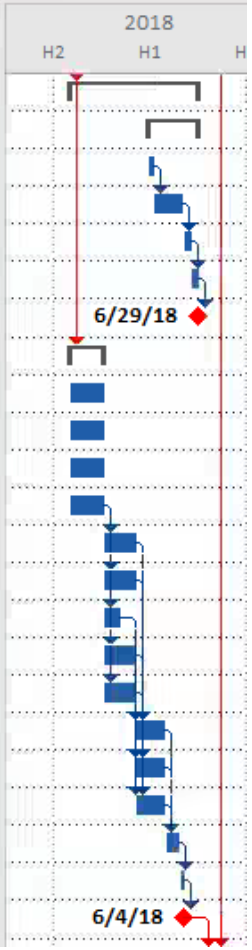
Project Schedule

WBS	Task Name	Duration	Start	Cost
1.3.2.1	**TPC Prototyping**	**685 days**	**Thu 10/1/15**	**$1,190,556**
1.3.2.1.1	**TPC Prototype v1**	**490 days**	**Thu 10/1/15**	**$474,455**
1.3.2.1.1.1	**v1 Field Cage Prototype**	**375 days**	**Thu 10/1/15**	**$271,598**
1.3.2.1.1.2	**v1 Module Prototyping**	**190 days**	**Wed 12/14/16**	**$202,857**
1.3.2.1.1.2.1	**v1 Gas Enclosure**	**65 days**	**Wed 12/14/16**	**$26,883**
1.3.2.1.1.2.2	**v1 Common Module Mechanics**	**40 days**	**Thu 12/15/16**	**$65,105**
1.3.2.1.1.2.3	**v1a Module Prototype**	**95 days**	**Thu 12/15/16**	**$55,434**
1.3.2.1.1.2.4	**v1b Module Prototype**	**95 days**	**Wed 5/3/17**	**$55,434**
1.3.2.1.1.2.5	v1 Module Prototyping Complete	0 days	Mon 9/18/17	$0
1.3.2.1.2	v1 Magnet Test (v1a module)	20 days	Thu 6/1/17	$28,952
1.3.2.1.3	v1 Performance Review	10 days	Tue 9/19/17	$14,800
1.3.2.1.4	TPC v1 Prototype Complete	0 days	Mon 10/2/17	$0
1.3.2.1.5	**TPC Prototype v2**	**250 days**	**Tue 4/4/17**	**$565,963**
1.3.2.1.5.1	**v2 Field Cage Prototype**	**245 days**	**Tue 4/4/17**	**$366,318**
1.3.2.1.5.2	**v2 Module Prototyping**	**190 days**	**Wed 6/28/17**	**$199,646**
1.3.2.1.6	Performance review v2 prototype	10 days	Fri 4/6/18	$8,312
1.3.2.1.7	TPC Prototype v2 Complete	0 days	Thu 4/19/18	$0
1.3.2.1.8	**TPC Preproduction Prototype**	**164 days**	**Wed 11/1/17**	**$98,074**



Project Schedule

WBS	Task Name	Duration	Start	Cost
1.3.2.1.8	**TPC Preproduction Prototype**	**164 days**	**Wed 11/1/17**	**$98,074**
1.3.2.1.8.1	**v2 Field Cage Modifications**	**65 days**	**Fri 3/30/18**	**$12,995**
1.3.2.1.8.1.1	Design v2 Field Cage Modifications	5 days	Fri 3/30/18	$7,400
1.3.2.1.8.1.2	Procure v2 Field Cage Modification Parts	40 days	Fri 4/6/18	$5,595
1.3.2.1.8.1.3	Perform Modification of v2 Field Cage	10 days	Mon 6/4/18	$0
1.3.2.1.8.1.4	Test Modified v2 Field Cage	10 days	Mon 6/18/18	$0
1.3.2.1.8.1.5	v2 Field Cage Modifications Complete	0 days	Fri 6/29/18	$0
1.3.2.1.8.2	**Site Prep for Production Factories**	**40 days**	**Wed 11/1/17**	**$36,000**
1.3.2.1.8.2.1	R1 Factory Preparation	40 days	Wed 11/1/17	$12,000
1.3.2.1.8.2.2	R2 Factory Preparation	40 days	Wed 11/1/17	$12,000
1.3.2.1.8.2.3	R3 Factory Preparation	40 days	Wed 11/1/17	$12,000
1.3.2.1.8.3	Design R1,R2,R3 Modules (strongback, frame, grid, pad, GEMs	40 days	Wed 11/1/17	$0
1.3.2.1.8.4	Procure R1,R2,R3 Stongbacks	40 days	Thu 1/4/18	$11,595
1.3.2.1.8.5	Procure R1,R2,R3 Frames	40 days	Thu 1/4/18	$8,595
1.3.2.1.8.6	Procure R1,R2,R3 Grids	20 days	Thu 1/4/18	$4,298
1.3.2.1.8.7	Procure R1,R2,R3 Pad Planes	40 days	Thu 1/4/18	$4,595
1.3.2.1.8.8	Procure R1,R2,R3 GEMs	40 days	Thu 1/4/18	$12,595
1.3.2.1.8.9	Assemble R1 Module in R1 Factory	40 days	Mon 3/5/18	$0
1.3.2.1.8.10	Assemble R2 Module in R2 Factory	40 days	Mon 3/5/18	$0
1.3.2.1.8.11	Assemble R3 Module in R3 Factory	40 days	Mon 3/5/18	$0
1.3.2.1.8.12	Test R1,R2,R3 Modules after Shipping to BNL	20 days	Mon 4/30/18	$0
1.3.2.1.8.13	Production Readiness Review	5 days	Tue 5/29/18	$7,400
1.3.2.1.8.14	Preproduction Prototype Accepted	0 days	Mon 6/4/18	$0



Description of Project Plan

- sPHENIX TPC has multi-stage R&D program:
  - *v1* prototype
  - *v2* prototype
  - *Pre-production* prototype
- Much R&D on GEM-based detectors done via the eRD6 program → EIC Detector R&D
- R&D should address "scaling issue" of large MPGD already at v1 level
- Propose to keep and use the *v2 (v1?)* field cage for the actual sPHENIX experiment
- *v1* phase has received funds from SBU and LDRD → must be considered in MS Project file correctly

Project Items

v1 Field Cage Prototype | **188,718** | **(including 20% cont.)**

Item	Vendor	Min Units	Ordered	Price	Total	Status	Basis of Estimate	SubComponent Total
FR4520 tooling Foam	General Plastics	6	7	623.14	$4,361.98	ORDERED		
2" diameter 9' long shaft	Technico	1	1	335	$335.00	DELIVERED		
RSF-14B-30-F100-24B	Harmonic Drive	1	1	1330	$1,330.00	ORDERED		
SHA32A161SG-B12BLV-10S17b-AN	Harmonic Drive	1	1	4674	$4,674.00	ORDERED		
8020	McMaster-Carr				$4,277.84	DELIVERED		
Laminate Trimmer	Grainger	1	1	155	$155.00	DELIVERED		
Position Encoders	Renishaw				$1,202.00	DELIVERED		
Adhesive, lab supplies	McMaster-Carr				$1,440.43	DELIVERED		
Lead Screw	Lin Tech				$3,456.00	DELIVERED		
2" flanged Collars for motor/encoder	McMaster-Carr				$371.66	DELIVERED		
USB microscope	Microscope Store				$143.00	DELIVERED		
Motor Controllers	Copley Controls				$1,637.00	DELIVERED		
SM encoder	Automation Direct				$67.25	DELIVERED		
SM motor	MicroMo				$253.49	DELIVERED		
Wire/connectors	DigiKey				$352.41	DELIVERED		
PS for translation motor (24 V 24 A)	Automation Direct				$415.00	DELIVERED		
PS for shaft motor (48 V 24 A)	Acopian				$1,170.00	ORDERED		
Motor Controller Access. Kits	Copley Controls				$276.00	ORDERED		
Web Tension Applicator Toolset	F.W. Hall Company				$4,000.00	Pending	Web Search	$29,918.06
Honeycomb	Plascorp	4	6	270.18	$1,621.08	DELIVERED		
Striped circuit cards	All-flex	5	8	2925	$23,400.00	Pending	Manufacturer Quote	
3 mil kapton 44" x 108 LF	Dunmore	2	3	7260	$21,780.00	Pending	Manufacturer Quote	
3 mil kapton 22" x 108 LF	Dunmore	4	5	4070	$20,350.00	Pending	Manufacturer Quote	
FR4 outer sheets 4' x 4'	ePlastics	8	10	114.58	$1,145.80	Pending	Manufacturer Quote	
HVPW resistors	DigiKey	800	1000	1.17	$1,170.00	Pending	Manufacturer Quote	
High Voltage Cable	Dielectric Sciences				$600.00	Pending	Web Search	$70,066.88
Striped circuit cards	All-flex	5	8	1500	$12,000.00	Pending	Manufacturer Quote	
3 mil kapton 44" x 108 LF	Dunmore	1	1	7260	$7,260.00	Pending	Manufacturer Quote	
3 mil kapton 44" x 108 LF	Dunmore	1	2	4070	$8,140.00	Pending	Manufacturer Quote	
FR4 Sheets 4' x 4'	ePlastics	2	2	114.58	$229.16	Pending	Manufacturer Quote	
HVPW Resistors	DigiKey	800	1000	1.17	$1,170.00	Pending	Manufacturer Quote	$28,799.16
Central Membrane					$8,000.00		Experience	$8,000.00
End Caps					$20,000.00		Experience	$20,000.00

Project Items

v1 Field Cage Prototype 188,718 (including 20% cont.)

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Laminate Trimmer	Grainger	1	1	155	$155.00	DELIVERED		
Position Encoders	Renishaw				$1,202.00	DELIVERED		
Adhesive, lab supplies	McMaster-Carr				$1,440.43	DELIVERED		
Lead Screw	Lin Tech				$3,456.00	DELIVERED		
2" flanged Collars for motor/encoder	McMaster-Carr				$371.66	DELIVERED		
USB microscope	Microscope Store				$143.00	DELIVERED		
Motor Controllers	Copley Controls				$1,637.00	DELIVERED		
SM encoder	Automation Direct				$67.25	DELIVERED		
SM motor	MicroMo				$253.49	DELIVERED		

v2 Field Cage Prototype 188,718 (including 20% cont.)

Motor Controller Access. Kits	Copley Controls				$276.00	ORDERED		
Web Tension Applicator Toolset	F.W. Hall Company				$4,000.00	Pending	Web Search	$29,918.06
Honeycomb	Plascorp	4	6	270.18	$1,621.08	DELIVERED		
Striped circuit cards	All-flex	5	8	2925	$23,400.00	Pending	Manufacturer Quote	
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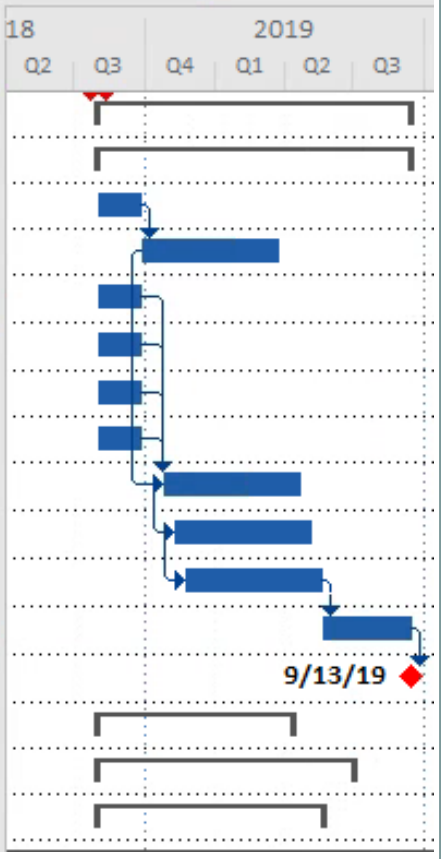
FR4 Sheets 4' x 4'	ePlastics	2	2	114.58	$229.16	Pending	Manufacturer Quote	
HVPW Resistors	DigiKey	800	1000	1.17	$1,170.00	Pending	Manufacturer Quote	$28,799.16
Central Membrane					$8,000.00		Experience	$8,000.00
End Caps					$20,000.00		Experience	$20,000.00

Project Items

WBS	Task Name	Durati	Cost	Fixed Cost
1.3.2.2	**TPC Production**	**280 days**	**$1,368,161**	**$0**
1.3.2.2.1	**TPC Module Production**	**280 days**	**$695,527**	**$0**
1.3.2.2.1.1	Train Technician to work in CERN Shop	2 mons	$39,080	$39,080
1.3.2.2.1.2	Production of GEM foils (includes Technician)	6 mons	$191,089	$191,089
1.3.2.2.1.3	Procure frames	40 days	$45,920	$40,000
1.3.2.2.1.4	Procure strongbacks (R1, R2, R3 modules)	40 days	$50,920	$45,000
1.3.2.2.1.5	Procure Pad Planes	40 days	$2,595	$0
1.3.2.2.1.6	Procure Grids	40 days	$2,595	$0
1.3.2.2.1.7	Build modules	6 mons	$155,712	$0
1.3.2.2.1.8	Test modules	6 mons	$0	$0
1.3.2.2.1.9	Assemble detector	6 mons	$155,712	$0
1.3.2.2.1.10	Test Detector Prior to installation	80 days	$51,904	$0
1.3.2.2.1.11	TPC Ready to install	0 days	$0	$0
1.3.2.2.2	**TPC Laser System**	**174 days**	**$241,907**	**$0**
1.3.2.2.3	**TPC Gas System**	**230 days**	**$260,997**	**$0**
1.3.2.2.4	**TPC Cooling System**	**202 days**	**$169,730**	**$0**



Project Items

WBS	Task Name	Durati	Cost	Fixed Cost
1.3.2.2				
1.3.2.2.1	**Train technician**	**39,080**		
1.3.2.2.1.1	Train Technician to work in CERN Shop	2 mons	$39,080	$39,080
1.3.2.2.1.2	Production of GEM foils (includes Technician)	6 mons	$191,089	$191,089
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1.3.2.2.1.4	Procure strongbacks (R1, R2, R3 modules)	40 days	$50,920	$45,000
1.3.2.2.1.5	Procure Pad Planes	40 days	$2,595	$0
1.3.2.2.1.6	Procure Grids	40 days	$2,595	$0
1.3.2.2.1.7	Build modules	6 mons	$155,712	$0
1.3.2.2.1.8	Test modules	6 mons	$0	$0
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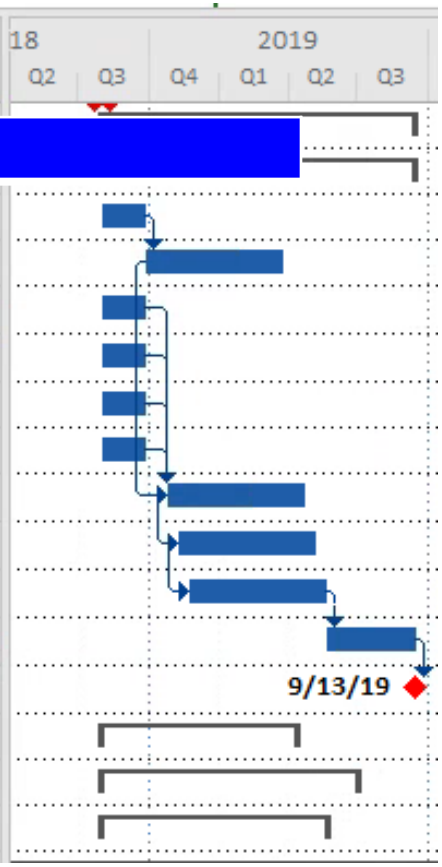

Project Items

WBS	Task Name	Durati	Cost	Fixed Cost
1.3.2.2				
1.3.2.2.1	**Train technician**	**39,080**		
1.3.2.2.1.1	**Production of GEM foils**	**191,089**		**(including technician)**
1.3.2.2.1.2	Production of GEM foils (includes Technician)	6 mons	$191,089	$191,089
1.3.2.2.1.3	Procure frames	40 days	$45,920	$40,000
1.3.2.2.1.4	Procure strongbacks (R1, R2, R3 modules)	40 days	$50,920	$45,000
1.3.2.2.1.5	Procure Pad Planes	40 days	$2,595	$0
1.3.2.2.1.6	Procure Grids	40 days	$2,595	$0
1.3.2.2.1.7	Build modules	6 mons	$155,712	$0
1.3.2.2.1.8	Test modules	6 mons	$0	$0
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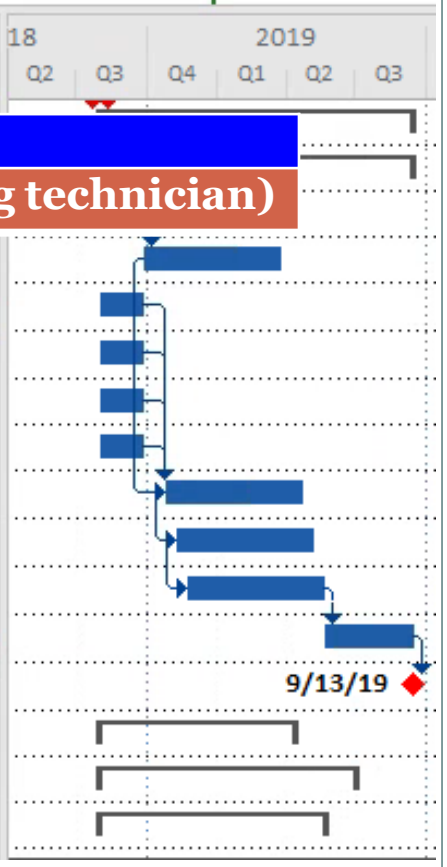
1.3.2.2.3	**TPC Gas System**	**230 days**	**$260,997**	**$0**
1.3.2.2.4	**TPC Cooling System**	**202 days**	**$169,730**	**$0**



Project Items

Train technician	**39,080**	
Production of GEM foils	**191,089**	**(including technician)**

3.1. Cost of GEM foils
Cost in CHF calculated per month, using 1 FSU technician.

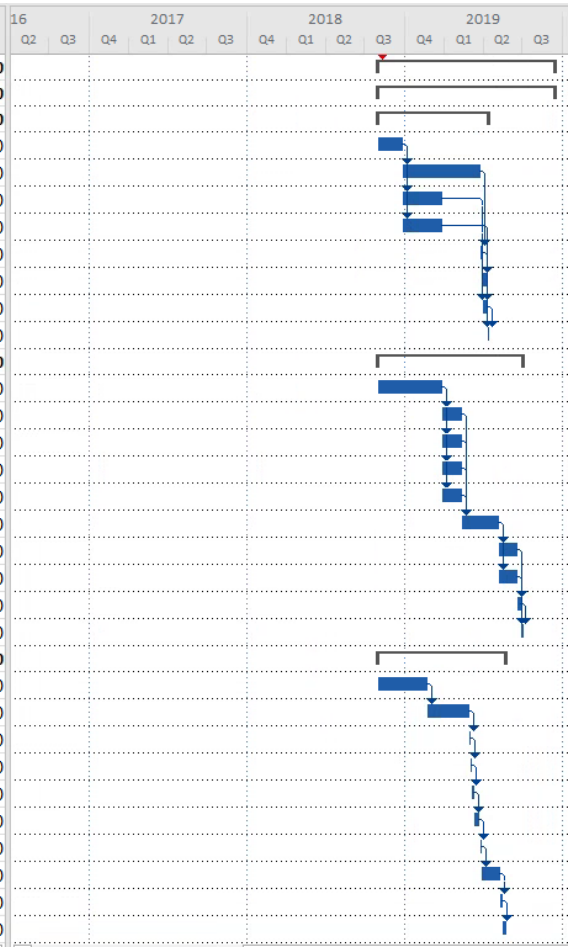
Cost/month/batch (CHF):	
Raw material	2750
Chemistry, photoresist, other consumables	1650
Personnel (1 FSU)	9000
TOTAL (100% yield)	13400
TOTAL (85% yield)	15410

Our production is based upon the rates shown in the above table as a scaling for the fact that we shall cover 1/3 the area of the ALICE upgrade.

Project Items

6

WBS	Task Name	Cost	Fixed Cost
1.3.2.2	**TPC Production**	**$1,368,161**	**$0**
1.3.2.2.1	**TPC Module Production**	**$695,527**	**$0**
1.3.2.2.2	**TPC Laser System**	**$241,907**	**$0**
1.3.2.2.2.1	Design Laser System & Safety	$59,200	$0
1.3.2.2.2.2	Procure lasers	$94,987	$90,000
1.3.2.2.2.3	Procure optics with mirrors	$52,494	$50,000
1.3.2.2.2.4	Procure mirror bundles with supports	$17,494	$15,000
1.3.2.2.2.5	Install lasers	$1,946	$0
1.3.2.2.2.6	saftey interlocks and paper work	$8,650	$2,000
1.3.2.2.2.7	Install optics with mounts	$5,190	$0
1.3.2.2.2.8	Install mirror bundles and supports	$1,946	$0
1.3.2.2.3	**TPC Gas System**	**$260,997**	**$0**
1.3.2.2.3.1	Design TPC Gas Handling System	$64,880	$0
1.3.2.2.3.2	Procure mass flow meters	$11,494	$9,000
1.3.2.2.3.3	Procure gas analyzer, 2 for rudundancy	$62,494	$60,000
1.3.2.2.3.4	Procure scrubbers	$6,494	$4,000
1.3.2.2.3.5	Procure oxygen and water sensors	$6,494	$4,000
1.3.2.2.3.6	Assemble gas system controls	$43,915	$0
1.3.2.2.3.7	Set up computer control system	$5,494	$3,000
1.3.2.2.3.8	plumbing and assembly	$48,422	$7,000
1.3.2.2.3.9	Set up interlocks	$7,156	$3,000
1.3.2.2.3.10	saftey reviews and paper work	$4,156	$0
1.3.2.2.4	**TPC Cooling System**	**$169,730**	**$0**
1.3.2.2.4.1	Design TPC Cooling System	$83,624	$0
1.3.2.2.4.2	Procure equipment(pumps,heat exchanger, PH control, enc	$38,880	$30,000
1.3.2.2.4.3	Install pumps	$1,946	$0
1.3.2.2.4.4	Install heat exchanger	$1,946	$0
1.3.2.2.4.5	Install PH control	$1,946	$0
1.3.2.2.4.6	Install end cap manifolds	$6,488	$0
1.3.2.2.4.7	Install tanks	$1,946	$0
1.3.2.2.4.8	Install plumbing	$23,464	$4,000
1.3.2.2.4.9	Set up controls	$6,244	$3,000
1.3.2.2.4.10	Set up interlocks	$3,244	$0



Project Items

6

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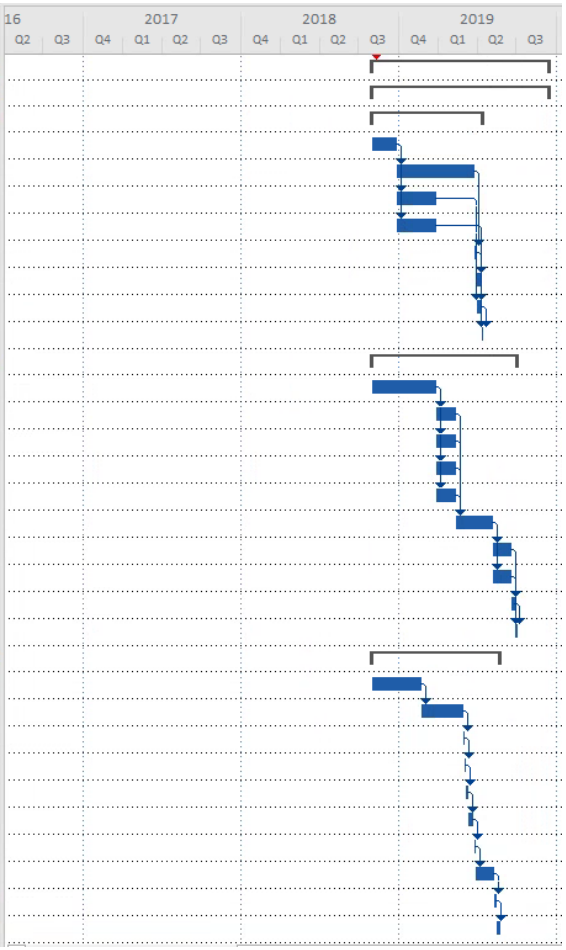
1.3.2.2.2.7	Install optics with mounts	$5,190	$0
1.3.2.2.2.8	Install mirror bundles and supports	$1,946	$0
1.3.2.2.3	**TPC Gas System**	**$260,997**	**$0**
1.3.2.2.3.1	Design TPC Gas Handling System	$64,880	$0
1.3.2.2.3.2	Procure mass flow meters	$11,494	$9,000
1.3.2.2.3.3	Procure gas analyzer, 2 for rudundancy	$62,494	$60,000
1.3.2.2.3.4	Procure scrubbers	$6,494	$4,000
1.3.2.2.3.5	Procure oxygen and water sensors	$6,494	$4,000
1.3.2.2.3.6	Assemble gas system controls	$43,915	$0
1.3.2.2.3.7	Set up computer control system	$5,494	$3,000
1.3.2.2.3.8	plumbing and assembly	$48,422	$7,000
1.3.2.2.3.9	Set up interlocks	$7,156	$3,000
1.3.2.2.3.10	saftey reviews and paper work	$4,156	$0
1.3.2.2.4	**TPC Cooling System**	**$169,730**	**$0**
1.3.2.2.4.1	Design TPC Cooling System	$83,624	$0
1.3.2.2.4.2	Procure equipment(pumps,heat exchanger, PH control, enc	$38,880	$30,000
1.3.2.2.4.3	Install pumps	$1,946	$0
1.3.2.2.4.4	Install heat exchanger	$1,946	$0
1.3.2.2.4.5	Install PH control	$1,946	$0
1.3.2.2.4.6	Install end cap manifolds	$6,488	$0
1.3.2.2.4.7	Install tanks	$1,946	$0
1.3.2.2.4.8	Install plumbing	$23,464	$4,000
1.3.2.2.4.9	Set up controls	$6,244	$3,000
1.3.2.2.4.10	Set up interlocks	$3,244	$0



Project Items

- **Details of the Base Estimate (explanation of the Work):** Procure Laser $90k, Optics and Mirrors $50k
  - Laser of appropriate power and pulse length must be purchased. sPHENIX called upon expertise of H. Wieman to select and cost appropriate laser for our needs based upon similar system used in ALICE
- **Assumptions Used in Developing Estimate**
  - Power and pulse length requirements on laser for sPHENIX well matched to those of ALICE

Project Items

- **Details of the Base Estimate (explanation of the Work):** Procure Gas Analyzer $60k
  - We shall use same gas analyzer systems as used for ALICE, costs of devices was shared with us by H. Wieman
- **Assumptions Used in Developing Estimate**
  - Cost of the gas analyzer will be similar when making our measurements
  - Quality of device should be same as in ALICE, latter criterion is conservative since ALICE operates away from drift velocity plateau and is more vulnerable to impurities

Bottoms-up Cost Estimate

- TPC MIE and Support Labor Costs fully burdened with BNL Project rates as applicable, escalated, and 40% contingency applied across the board. BNL Labor rates where appropriate. Reductions for BNL LDRD and SBU funding were applied.

sPHENIX TPC Tracking

Summary Estimate

	2016	2017	2018	2019	2020	2021	2022	Grand Total
sPHENIX Labor								
Fixed FY16 Direct Labor w/fringe		**372,981**	**493,559**	**551,504**	**149,820**			**$1,567,864**
Estimated Composite Indirect on Labor@36.9%	0	137,630	182,123	203,505	55,284	0	0	578,542
Fixed FY16 Fully Loaded Labor	**0**	**510,611**	**675,682**	**755,009**	**205,104**	**0**	**0**	2,146,406
Escalation @ 3.0%	0	15,318	41,149	69,989	25,740	0	0	152,197
Subtotal AY $	**0**	**525,929**	**716,831**	**824,998**	**230,844**	**0**	**0**	2,298,603
Contingency at 40%	0	210,372	286,733	329,999	92,338	0	0	919,441
Budgeted Labor	**0**	**736,301**	**1,003,564**	**1,154,998**	**323,182**	**0**	**0**	**3,218,044**
Adjusted sPHENIX M&S - TPC		**$324,866**	**$736,169**	**$893,000**	**$5,000**			**$1,959,035**
Estimated Composite Indirect	0	30,635	69,421	84,210	472	0	0	184,737
Subtotal FY 16 $	**$0**	**$355,501**	**$805,590**	**$977,210**	**$5,472**	**$0**		**$2,143,772**
Escalation @ 2% per FY	0	7,110	32,546	59,813	451	0		99,920
Estimate with Escalation	**$0**	**$362,611**	**$838,136**	**$1,037,023**	**$5,923**	**$0**		**$2,243,692**
Contingency at 40%	0	145,044	335,254	414,809	2,369	0	0	897,477
Budgeted Material	**$0**	**$507,655**	**$1,173,390**	**$1,451,832**	**$8,292**	**$0**	**$0**	**$3,141,169**
Total AY $ with Contingency Estimate	**$0**	**$1,243,956**	**$2,176,954**	**$2,606,830**	**$331,473**	**$0**	**$0**	**$6,359,213**
Overall contingency %								**40.0% TPC**
								40.0% TEC

Outlook

- Suggest we take on Drill-Down Exercise

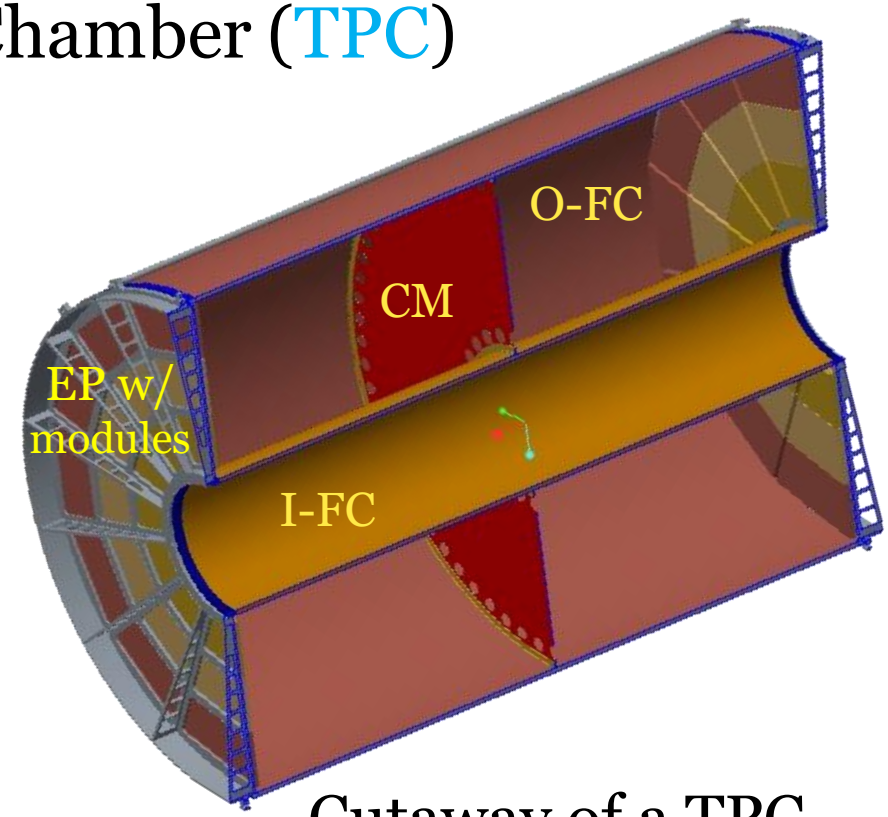
Project Scope

- Build a Time Projection Chamber (TPC)
  - Field Cage (FC)
  - Endplate (EP)
    - Modules
    - Electronics
  - Central Membrane (CM)
  - Readout Electronics

Field Cage subdivided in

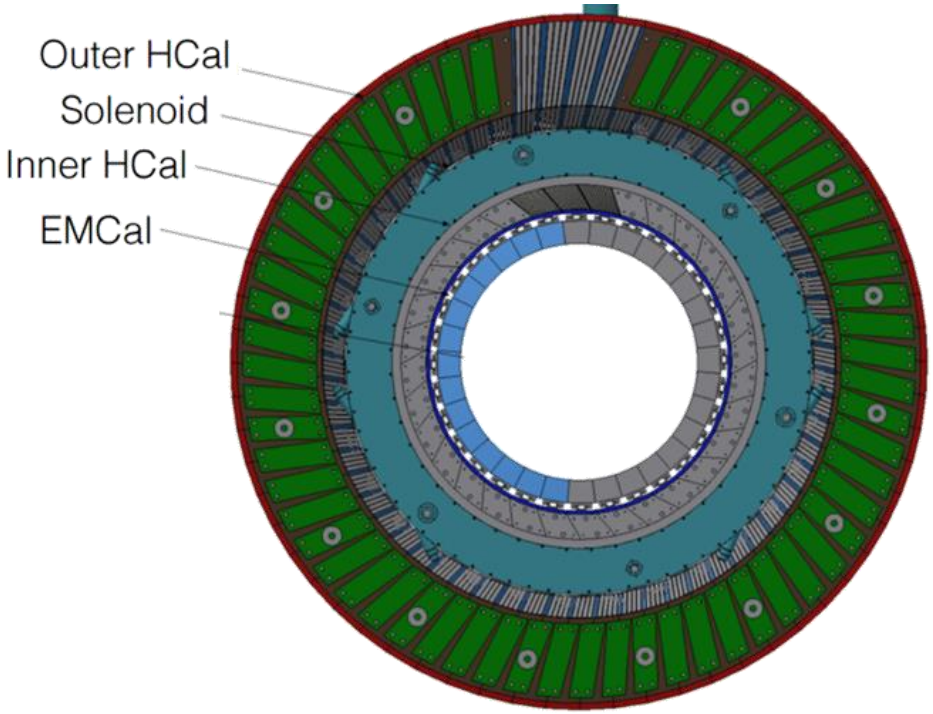
Outer (O-FC)

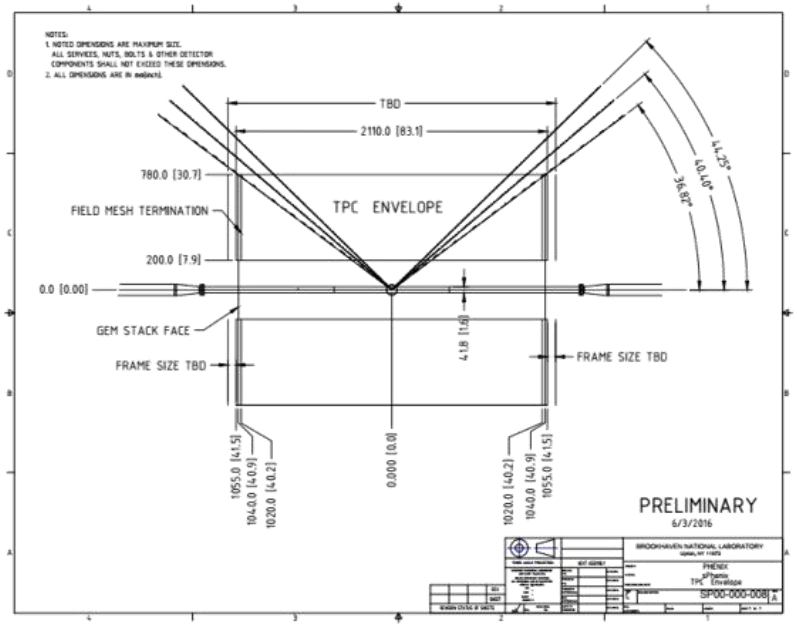
Inner (I-FC)



Cutaway of a TPC

Project Scope

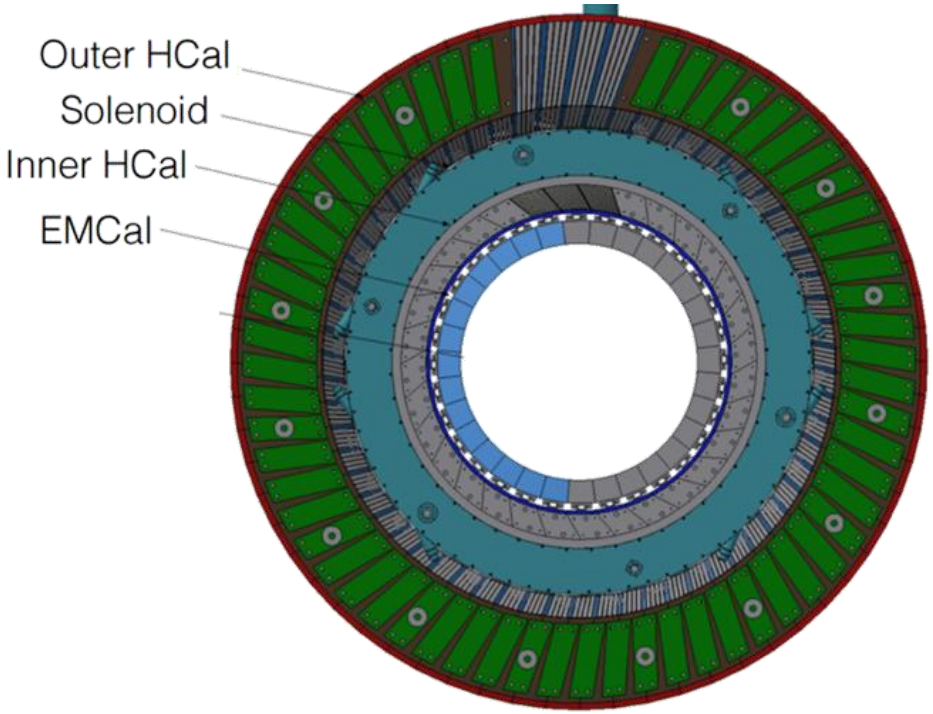


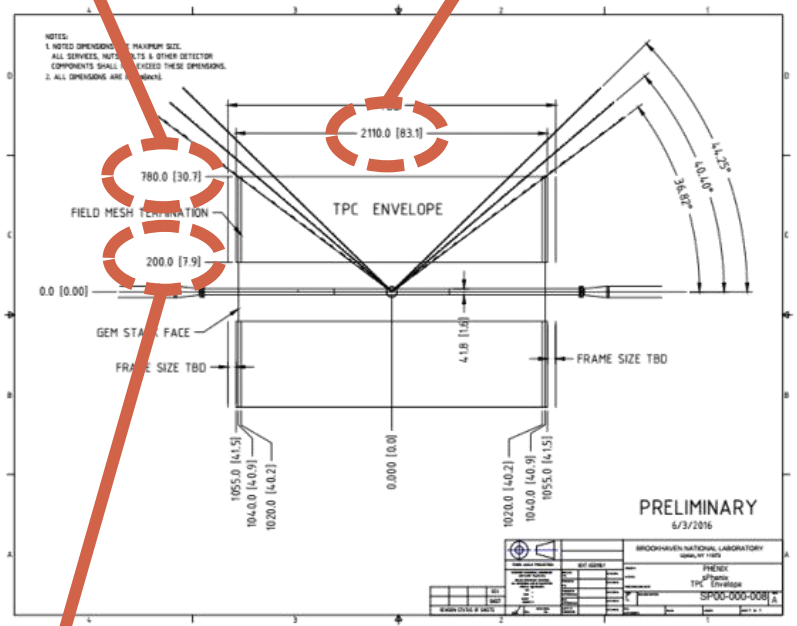


Project Scope

l = 2110.0 mm (83.1 in)

OR = 780.0 mm (30.7 in)



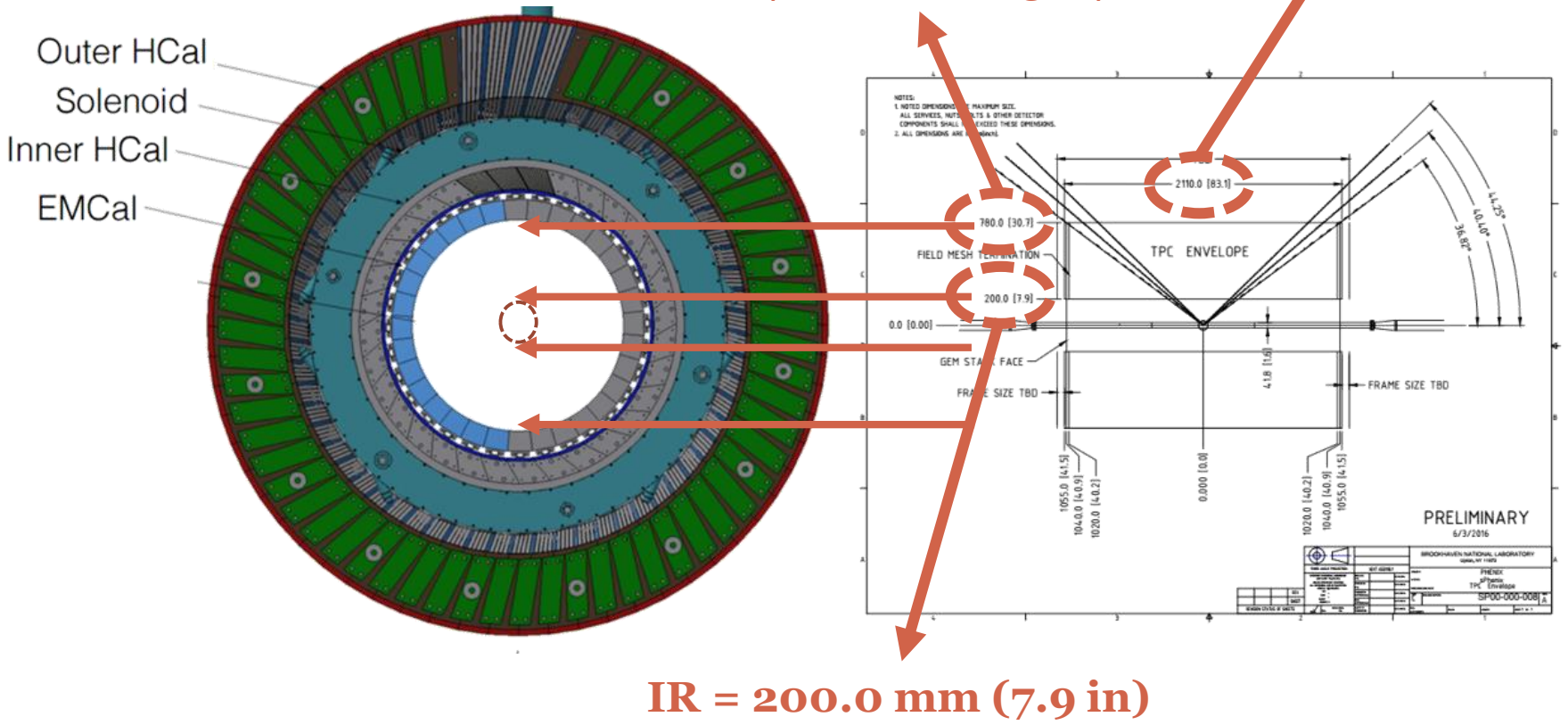


IR = 200.0 mm (7.9 in)

Project Scope

l = 2110.0 mm (83.1 in)

OR = 780.0 mm (30.7 in)



IR = 200.0 mm (7.9 in)